Dust Disks around Pulsars

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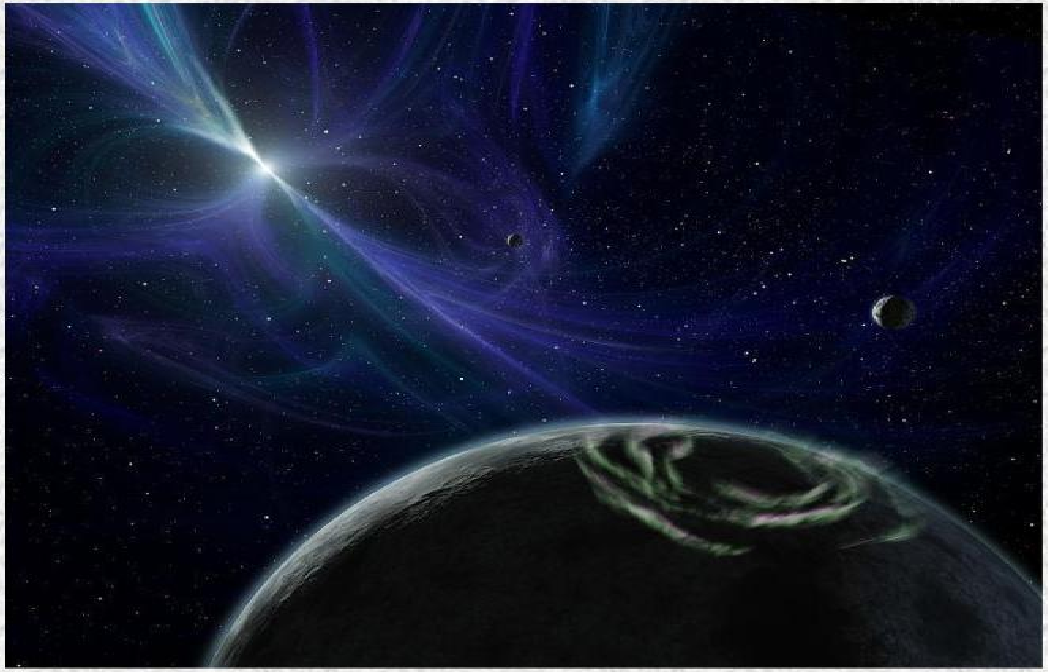
Outline

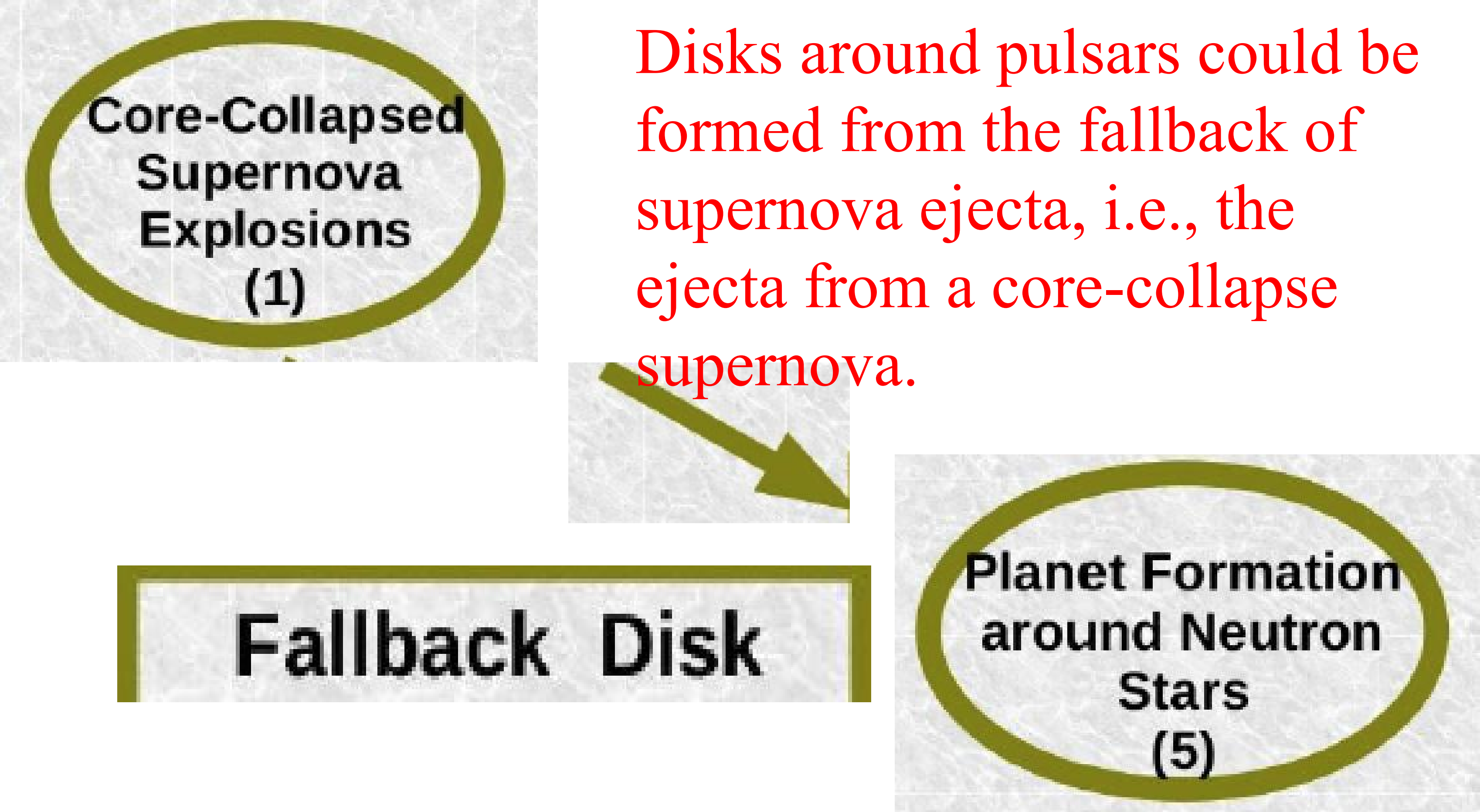
- **1 Background**
- **2 Data Sources**
- **3 Method**
- **4 Results**
- **5 Future plan**

- The first extrasolar planetary system was found around PSR B1257+12, a millisecond pulsar (Wolszczan & Frail 1992)



Planet	Mass (Earth mass)	Orbit
A	0.02	25 days (0.19 AU)
B	4.3	66 days (0.36 AU)
C	3.9	98 days (0.46 AU)

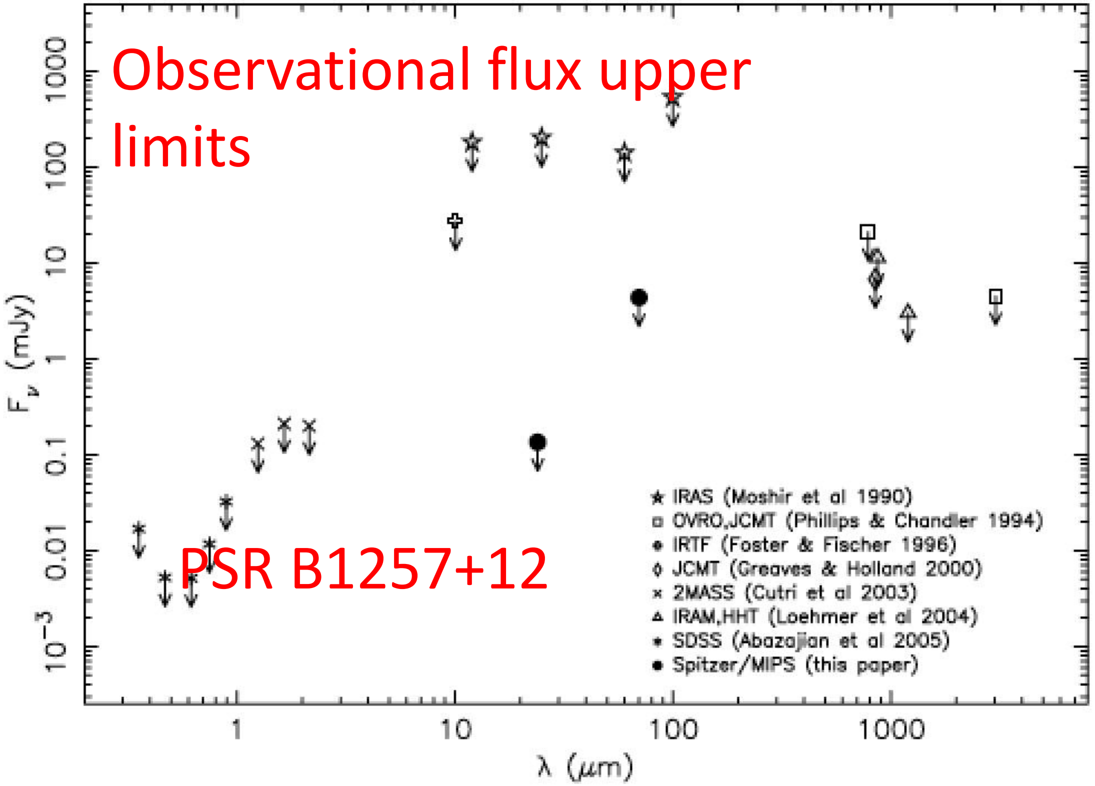
Disks around pulsars could be formed from the fallback of supernova ejecta, i.e., the ejecta from a core-collapse supernova.



The ejecta from a core-collapse supernova could be captured by the gravitational field of the newly formed neutron star and therefore fall back onto the star and form an orbiting disk.

The ejecta from core-collapse supernovae falls back toward the central neutron star ⇨ forms a disk orbiting the star.

*H*eated by the ultraviolet and X-ray photons converted from the spin-down energy of the pulsar, the dust in the disk is expected to radiate thermally in the infrared (IR).



Observational flux upper limits

PSR B1257+12

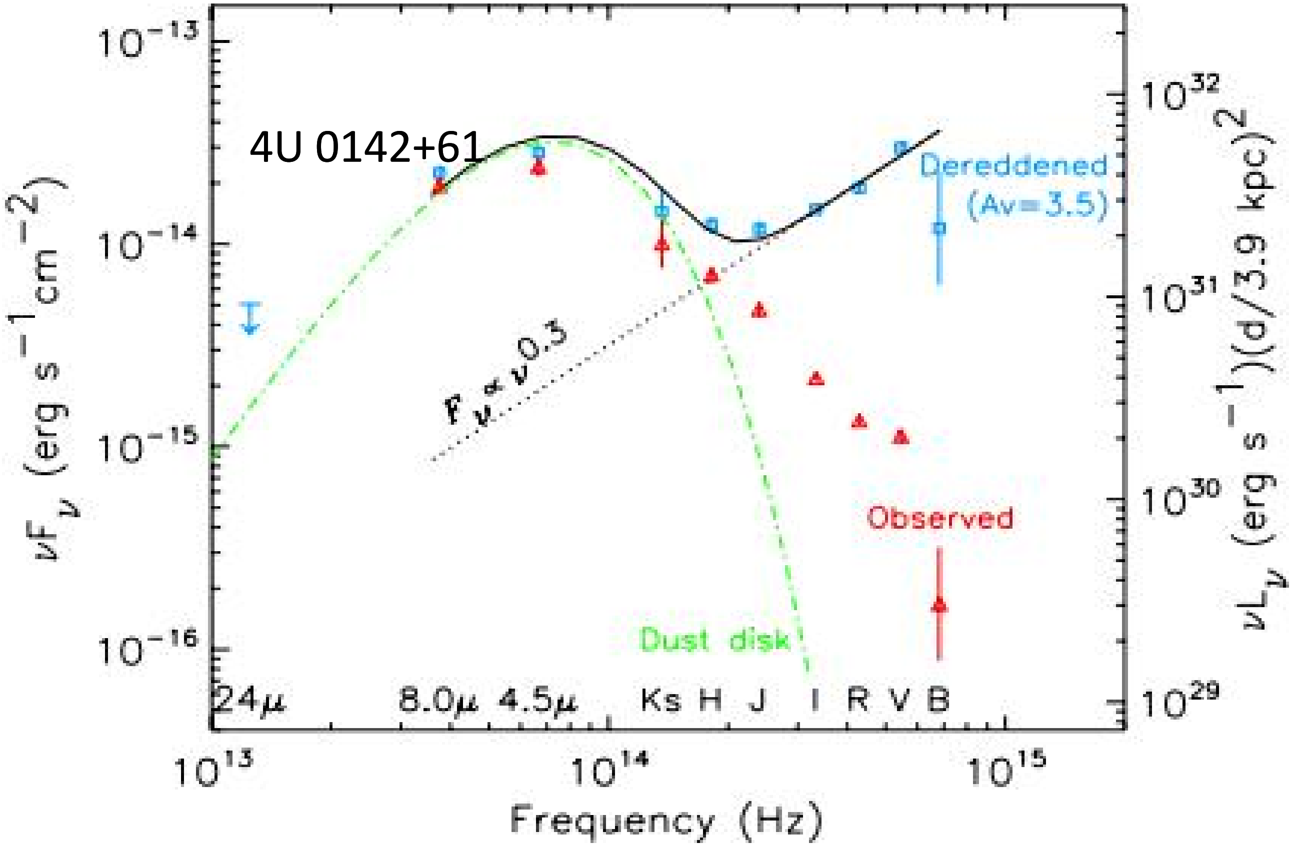
Bryden et al. 2006

The search for dust thermal emission from the near-IR to millimeter (mm) so far has mostly been unsuccessful. *Spitzer*/IRAC detections of the 4.5 and 8μm dust emission in two magnetars were reported.

Age: 70,000 yr

B=1.3E14 G magnetar

Wang et al. (2006)



Pulsars parameter

Pulsar	P (s)	d (pc)	logE (erg/s)	Companions	Reference
B1534+12	0.038	1080	33.25	neutron star	Stairs et al.(1998)
J2322+2057	0.0048	780	33.40	isolated	Nice et al.(1993)
J2019+2425	0.0039	910	33.73	white dwarf	Nice et al.(1993)
B0149-16	0.8	790	31.95	isolated	siegman et al.(1993)
B1604-00	0.42	590	32.21	isolated	Philipps&Wolszczan(1992)
J0108-1431	0.85	85	30.78	isolated	Tauris et al.(1994)
B1855+09	0.005	900	30.31	white dwarf	Kaspi,Taylor&Ryba(1994)
B1257+12	0.0062	620	34.30	planets	Wolszczan(1993)

Data Sources

- IRTF（Infrared Telescope Facility)
- 10μm （Foster et al.1995）

- ISO（Infrared Space Observatory ）
- 15μm,90μm(L.Koch-Miramond et.al2014)

- IRAS(Infrared Astronomical Satellite)
- 12μm,25μm,60μm,100μm(Miramond et.al 2002)

Data Sources

- ISO(Infrared Space Observatory)
- 60µm,90µm(Joseph et.al2004)

- JCMT(James clerk Maxwell Telescope)
- 850µm(Greaves et.al2006)

- HHT(Heinrich-Hertz-Telescope)
- 870µm(Wielebinski et.al2014)

Data Sources

- IRAM(institute for radio astronomy)
- 1200μm(Wielebinski et.al2014)

- Spitzer
- 24μm,70μm(Bryben et.al2006)

Method

- Let the far-IR opacity be $\kappa_\lambda \propto \lambda^{-\alpha}$

$$u_r \propto \mathrm{r}^{-2}$$

$$T_d \propto u_r^{\frac{1}{4+\alpha}} \quad \longrightarrow \quad \mathrm{T_d} \propto \mathrm{r}^{-\frac{2}{(4+\alpha)}}$$

$$T(r_{\min}) = T_0 \quad \longrightarrow \quad \mathrm{T}(r) = T_0\left(\frac{r}{r_{\min}}\right)^{-\frac{2}{4+\alpha}}$$

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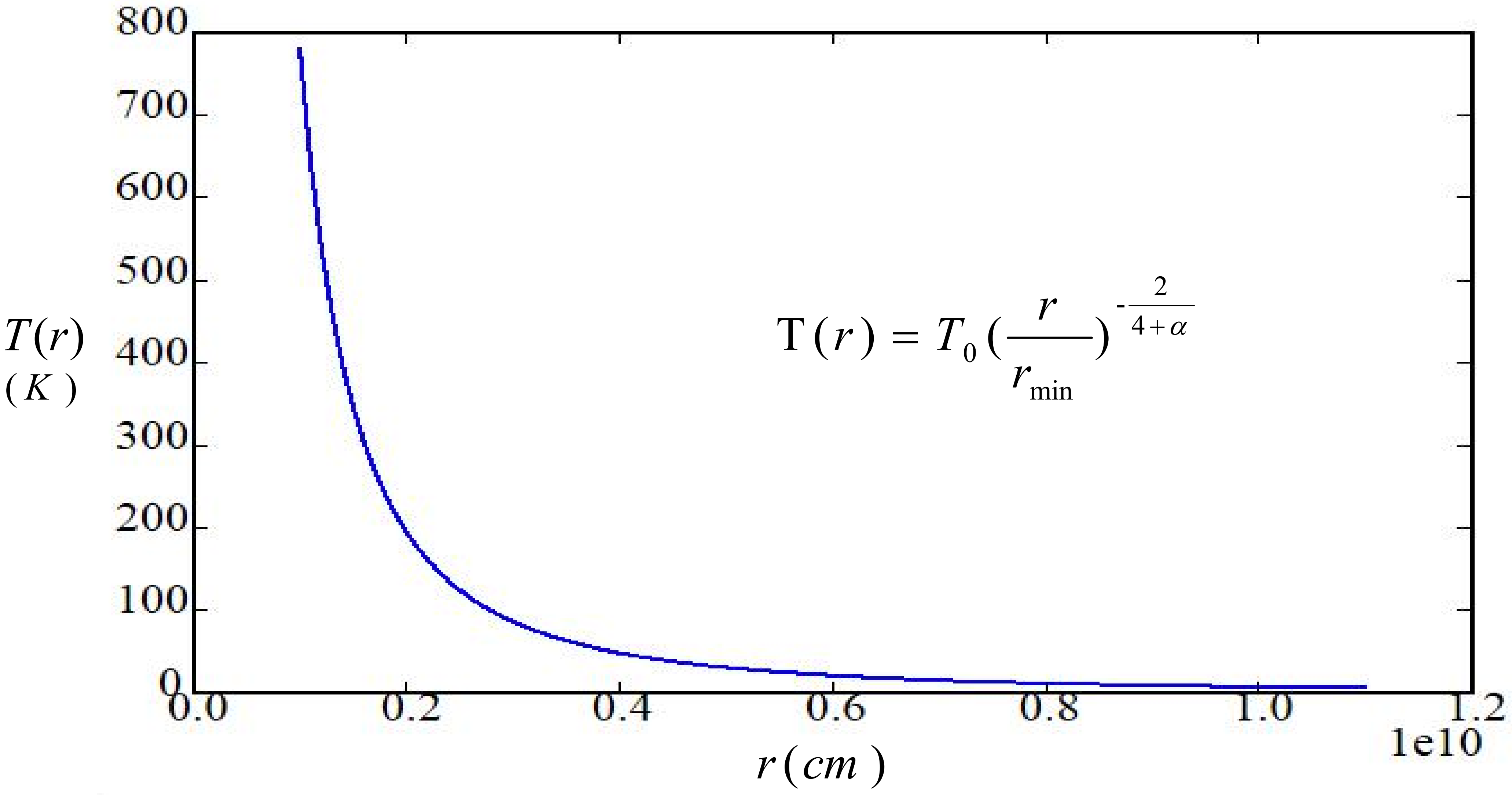

$$\mathrm{T}(r) = T_0\left(\frac{r}{r_{\min}}\right)^{-\frac{2}{4+\alpha}}$$

Method

$r_{\max}$ $\quad T(r_{\max}) = T_{ISM} \quad \rightarrow$

$$r_{\max} = r_{\min} . e^{\left[In\left(\frac{T_0}{T_{ISM}}\right) \cdot \frac{4+\alpha}{2} \right]}$$

Method

- flux density

$$F_\lambda = \frac{1}{4\pi d^2} \int_{r_{\min}}^{r_{\max}} C_{abs}(a, \lambda) 4\pi B_\lambda[T(r)] \sigma(r) 2\pi r dr$$

Method

- Let

$$\sigma(r) = \sigma_0 (1 - \frac{r_{\min}}{r})^{\beta} (\frac{r_{\min}}{r})^{\gamma}$$

when $r = r_{\min}$ $\quad$ $no \;\; dust$

$r >> r_{\min}$ $\quad$ $\sigma(r) \propto r^{-\gamma}$

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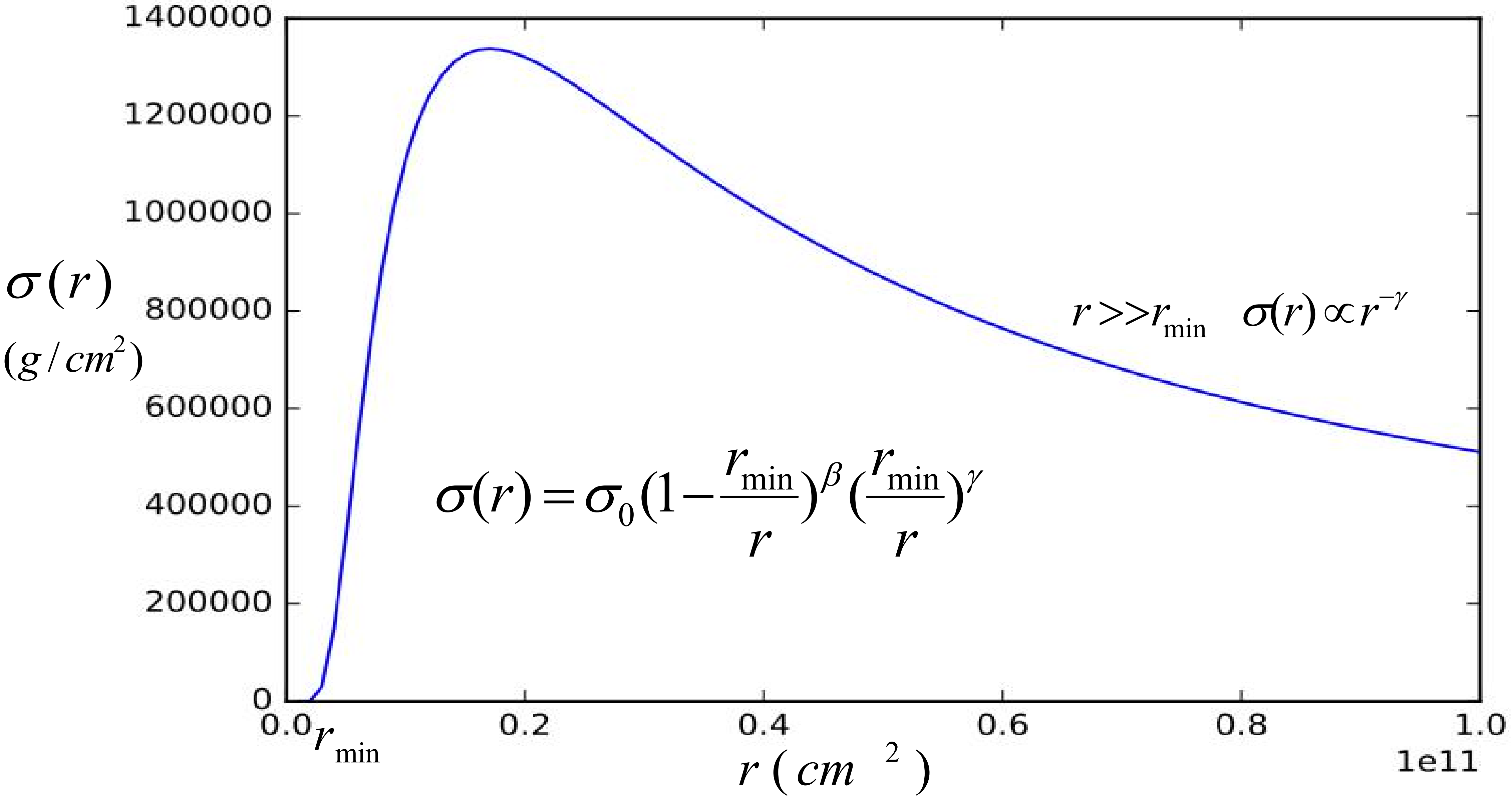


$$r \gg r_{\min} \quad \sigma(r) \propto r^{-\gamma}$$

$$\sigma(r) = \sigma_0 \left(1 - \frac{r_{\min}}{r}\right)^{\beta} \left(\frac{r_{\min}}{r}\right)^{\gamma}$$

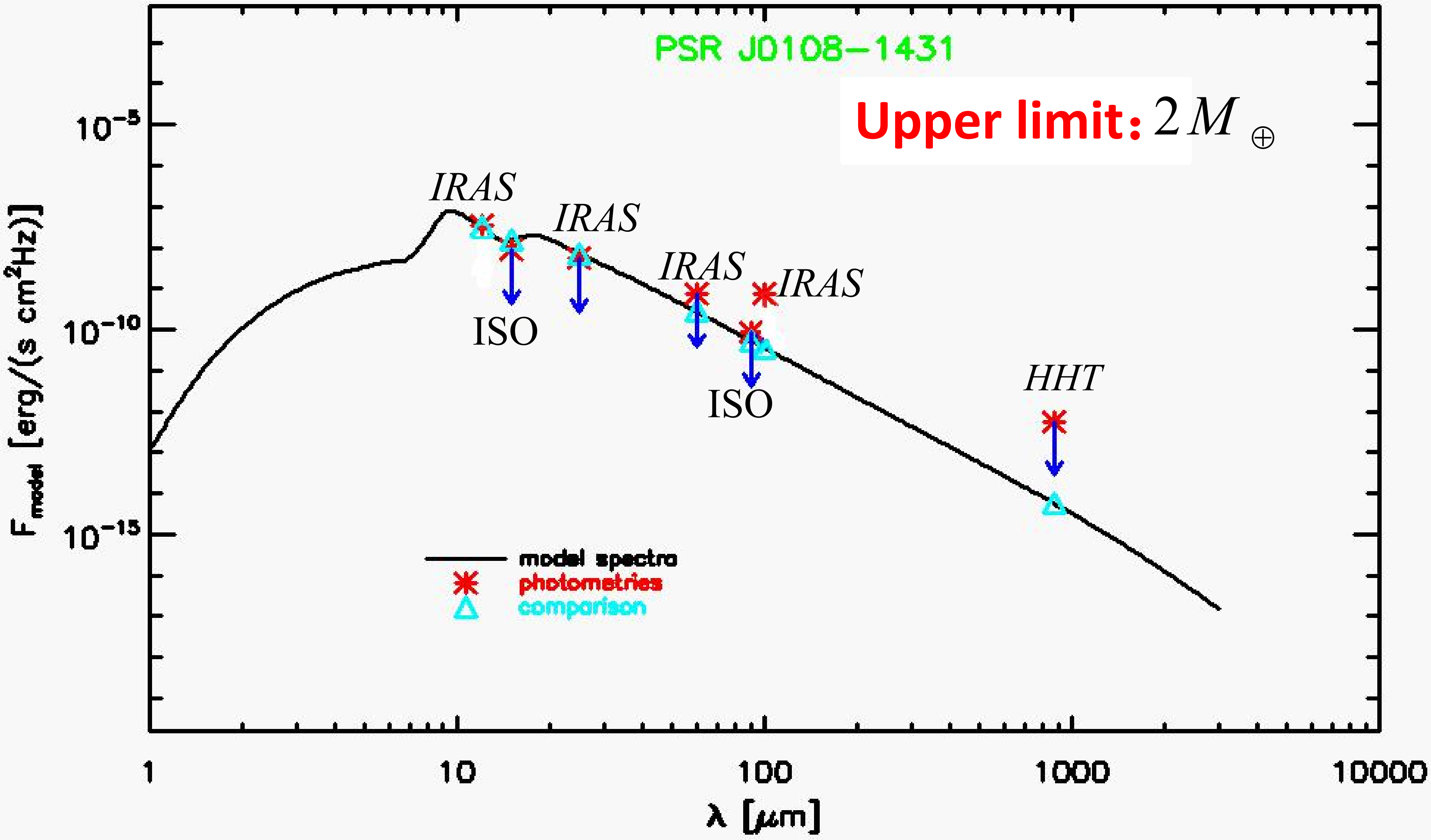
Method

$$M_{dust} = \int_{r_{\min}}^{r_{\max}} \left(\frac{4}{3}\pi a^3 \rho\right).\delta_0\left(1-\frac{r_{\min}}{r}\right)^{\beta}.\left(\frac{r_{\min}}{r}\right)^{\gamma}.2\pi r dr$$

Photometric data

PSRJ0108−1431

λ[μm]	12	15	25	60	90	100	870
F_ν[mJy]	170	66	110	90	22.5	250	14.5

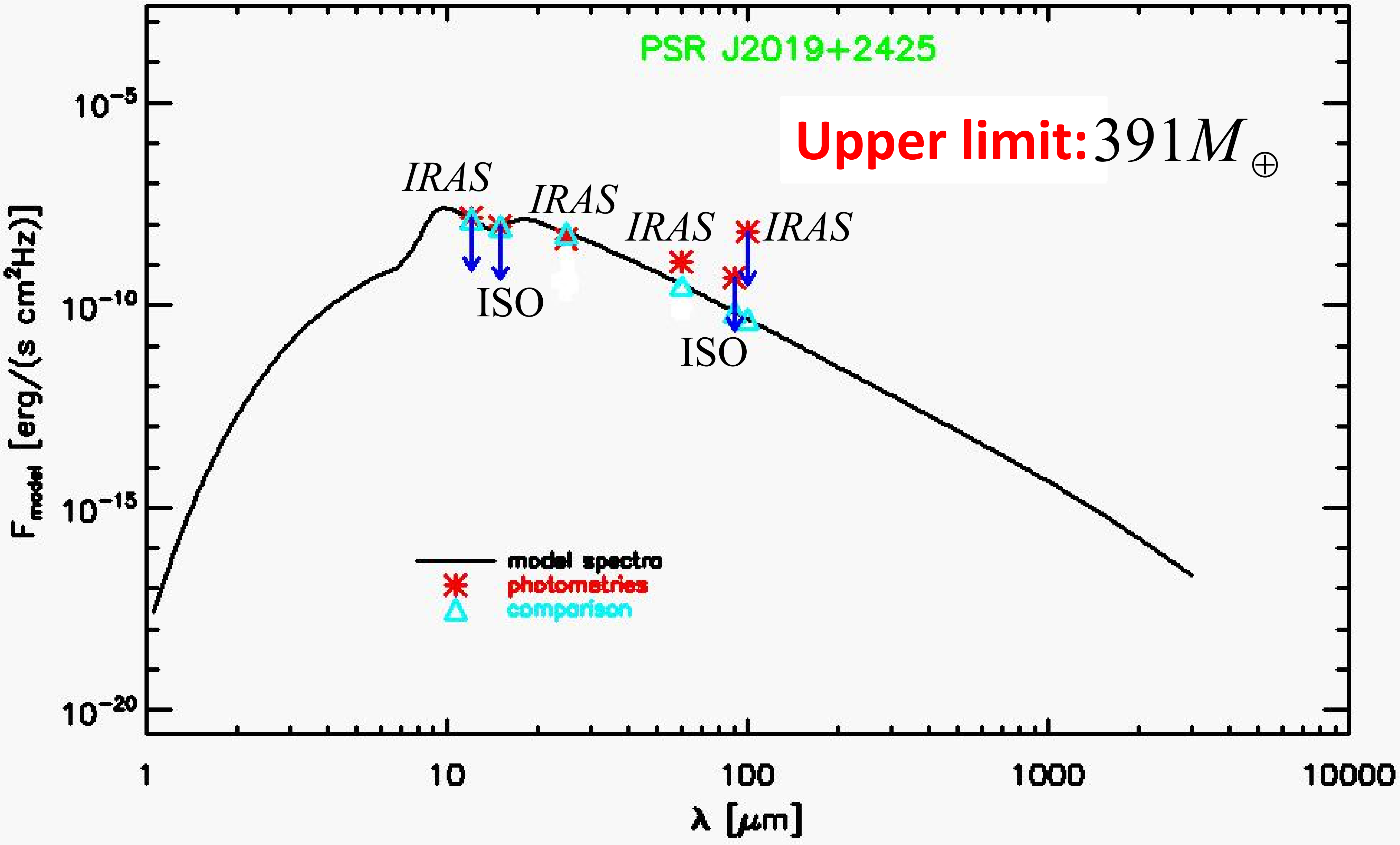


Upper limit：$2M_\oplus$

Photometric data

- **PSRJ2019+2425**

λ[μm]	**12**	**15**	**25**	**60**	**90**	**100**
F_ν[mJy]	70	64.5	90	140	130	2100

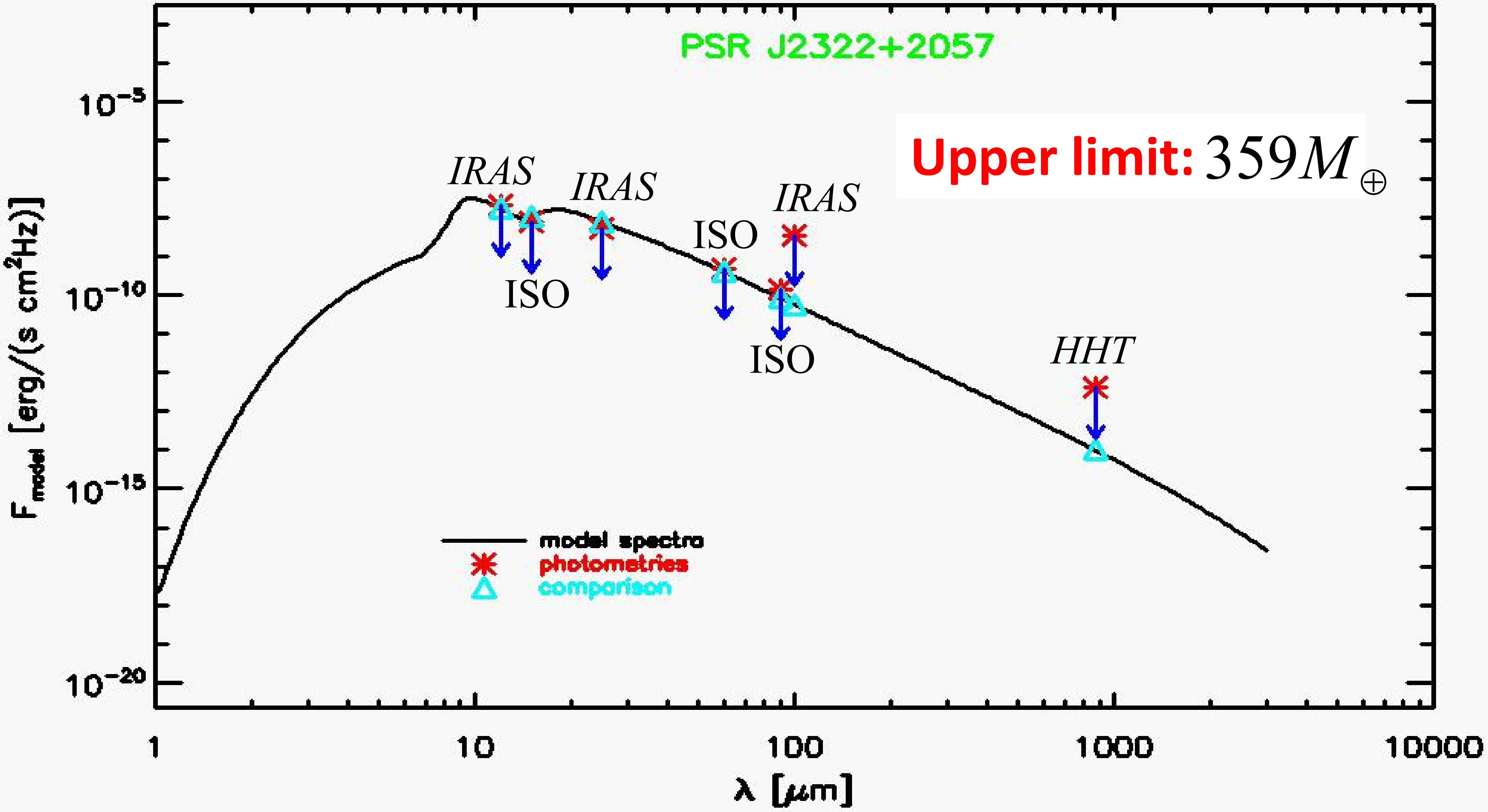


Upper limit: $391 M_{\oplus}$

Photometric data

PSRJ2322+2057

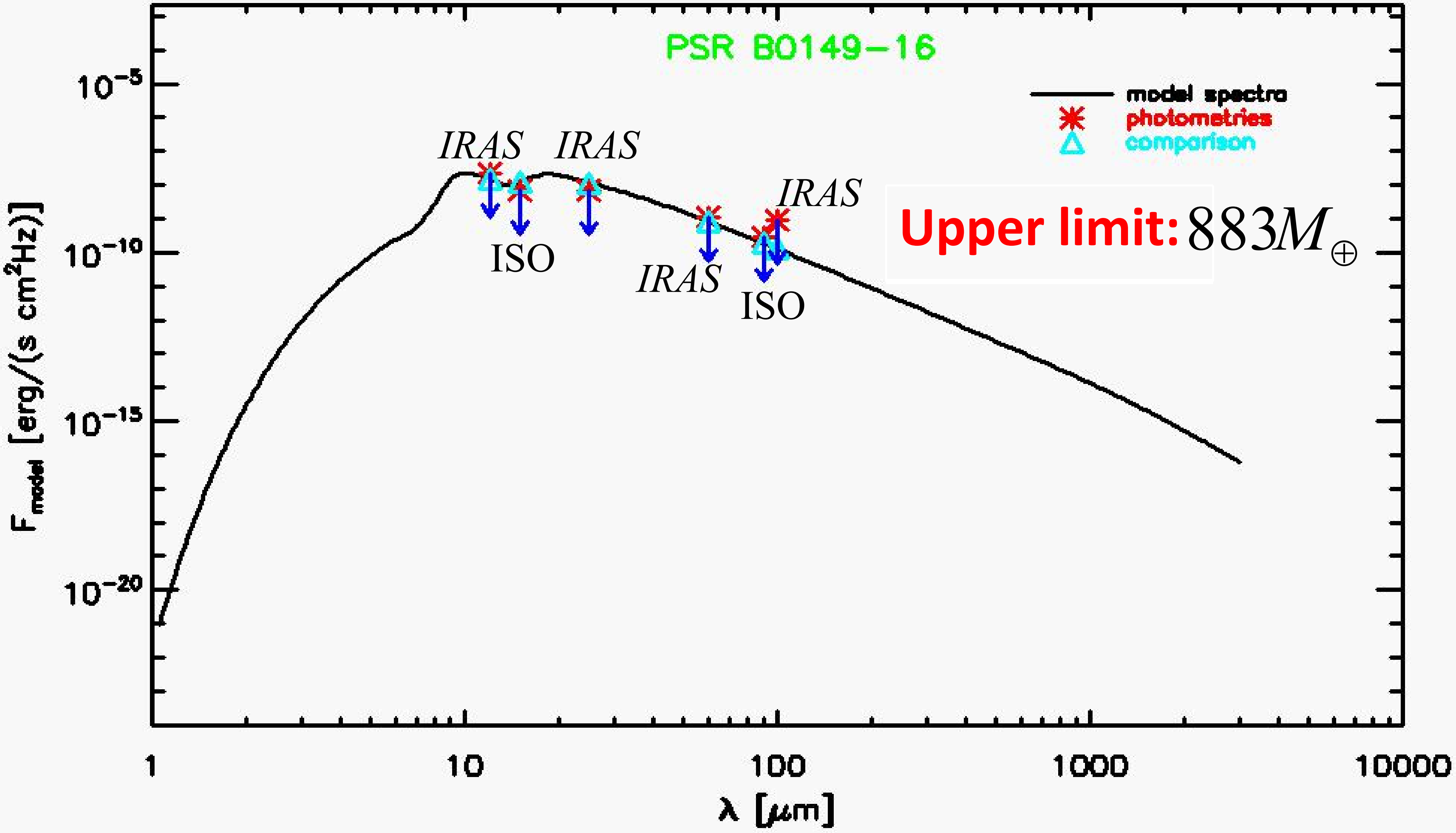
$\lambda[\mu m]$	**12**	**15**	**25**	**60**	**90**	**100**	**870**
$F_\nu[mJy]$	100	58.8	110	59	39	1200	10.2



Upper limit: $359M_\oplus$

Photometric data
PSRB0149–16

$\lambda[\mu m]$	12	15	25	60	90	100
$F_\nu[mJy]$	110	52.8	140	130	75	300



Upper limit: $883M_\oplus$

Future plan

- 1 Searching for more photometric data
- 2 More sources

THANKS